CONTAMINATION OF PRIVATE WELL WATER SUPPLIES

TOWN OF SMITH FALLS
TOWNSHIP OF MONTAGUE

by F. R. Campbell

1974

The Honourable
James A. C. Auld
minister

Ministry
of the
Environment

Ontario

Everett Biggs
deputy minister

MINISTRY OF THE ENVIRONMENT

TOWN OF SMITHS FALLS

TOWNSHIP OF MONTAGUE

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F. R. CAMPBELL

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ACKNOWLEDGEMENTS

The assistance of Dr. V. Soudek, Dr. A. Nicholson, Mr. J. Dart, Mr. F. Thompson, Mr. H. E. Shamsy, Mr. J. W. Vogt, and Mr. G. Clark in contributing to and critically reviewing this report is gratefully acknowledged.

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INTRODUCTION

In response to a request from Mr. George Clarke, Industrial Wastes Branch, Ottawa, an investigation was undertaken by the Water Quantity Management Branch to determine the source of contamination of private well water supplies in the Township of Montague at the eastern extremity of the Town of Smiths Falls. The study area is located with reference to the town in Figure 1 and a more detailed map of the study area is presented in Figure 2.

This study has included an office examination of the hydrogeology, physiography and water-well records for the area. Laboratory techniques have been developed for the determination of trace concentrations of ethyl acetate and toluene. Field work has included a precise levelling survey, an examination of local hydrogeologic features, and interviews with the local residents, industry representatives and municipal officials. The results of the chemical analyses of samples collected during the investigation are shown in Table 1. Water well and sampling locations are shown in Figure 2.

BACKGROUND

The complainants, Mr. and Mrs. J. Fountain, whose residence is located in Figure 2, were concerned about the sudden appearance of a dark coloured substance in their well water in the spring of 1973. The discolouration was accompanied by a strong "rotton egg" odour. The Fountains were of the opinion that the source of their well water contaminant was a waste ink dump site of the Rolph-Clark-Stone Company shown in Figure 2. It was claimed that the waste ink was leaching into the ground to enter the local aquifer and to pollute local drinking water supplies. The Fountains contacted the local health unit and as a result samples of their well water were collected for bacterial analysis. The Health Unit then requested assistance from the Public Health Engineering Section of the Ministry of Health. Mr. H. E. Shamsy visited the site on September 26, 1973, and completed a summary report of his findings on November 5, 1973. Portions of Mr. Shamsy's report are included in this report with his permission.

The Ministry of the Environment initiated an independent study of the problem as a result of a request by Mr. H. Lloyd, the town engineer for Smiths Falls. Mr. Lloyd was acting on behalf of the Fountains as a result of their further complaints. On October 15, 1973, the writer accompanied by Mr. Clarke visited the site and made the following observations:

1) The complainant's water appeared to contain hydrogen sulphide gas, H_2S, and iron sulphide giving the water a characteristic odour and appearance as described by the complainants.

2) The complainant's drilled well, which is located in a partially covered dry well in his workshop, did not have a proper sanitary seal.

3) The complainant's well is located topographically downgradient from a number of private septic systems that are found in very shallow soil over fractured limestone bedrock. The well is topographically upgradient from the Rolph-Clark-Stone dump site.

4) Waste material, primarily consisting of ink and cleaning solvent contaminated with paper particles, is dumped at the site shown in Figure 2 at a rate of about 10 gallons per week. On January 17, 1974, Mr. George Clarke received information from Rolph-Clark-Stone representatives that waste material probably was accumulated by the industry at a more representative rate of 70 gallons per week.

5) Large water takings from the bedrock aquifer are mainly confined to the Rolph-Clark-Stone and Hershey wells shown in Figure 2. These wells are downgradient from the complainant's well.

6) A second complainant, Mr. R. Carr, a neighbour of the Fountains was identified during Mr. Shamsy's and the present investigations. The Carrs stated that well water quality problems first appeared in August, 1973, but that their problems have never been as severe as the Fountains. Neither Mr. Shamsy nor the writer noticed any taste or odour problems in the Carr well water.

GEOLOGY

Smiths Falls is located about mid-way between Kingston and Ottawa at the junction of highways 15, 29 and 43. The study area, at the eastern extremity of Smiths Falls, lies on the town limits bordering the Township of Montague.

Physiographically the area lies on the Smiths Falls Limestone Plain[1], a large continuous tract of shallow soil overlying limestone bedrock. The exposed rock strata belong to the lower portion of the March and the Nepean formations and include calcareous sandstone and sandstone which overlies black granite of Precambrian age. The bedrock is flat bedded with an overall dip of about five feet per mile toward the northeast[1]. The rock is highly fractured and contains frequent zones of "lost circulation" between the sandstone bedding planes[2].

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1. Chapman, L. J. and D. F. Putnam, 1966, the Physiography of Southern Ontario, 2nd Edition, published for the Ontario Research Foundation by University of Toronto Press, 1966.

2. Personal communication, W. Morrison, local well driller.

Overlying the bedrock at thicknesses up to approximately eight feet is a sandy loam of the Farmington series. This moderately-stoney, well-drained sandy loam till material is a very shallow-phase development of the Farmington series on sandstone[3].

HYDROGEOLOGY

The surficial sandy loam till material is too thin to serve as even a minor source of local ground-water supply. The overburden is saturated to the southeast of the study area in a swampy area containing muck soils but nowhere else are the overburden materials saturated. Because of the well drained nature of the till material, any liquid contaminants lost at ground surface will penetrate through the soil to enter the underlying fractured rock.

The major aquifers in the area are contained within the sandstone bedrock. All of the wells in the study area are drilled into these bedrock aquifers. Water well records indicate that wells will extend from 40 feet to 200 feet into the bedrock. The average depth of rock penetration is about 70 feet. The drilled wells are reported to produce quantities of water up to 650 gpm. Domestic supplies appear to be sufficient without any complaint of water shortage. A shortage of water has been experienced during mid-summer periods at the Rolph-Clark-Stone plant. Pumping from two wells at 250 gpm each has caused sufficient drawdown in the wells that company representatives have allowed the wells to recover for periods up to two weeks to prevent damage to their pumps. The water appears to be fresh.

In bedrock aquifers ground water tends to move primarily through fractures under the influence of gravity from topographically high areas toward topographically low areas. Thus, water flow in the aquifers being considered would be expected to be in a southeastwardly direction from the topographically high area at the northwestern extremity of the study area toward the Rolph-Clark-Stone property at the southeastern end of the area.

Several rock aquifers are present in the immediate study area and flow directions in these aquifers are not clearly understood. A tracer study was completed by Ministry of Health representatives to assist in determining underground flow patterns. A fluorescein dye was put into the stream shown in Figure 1 at the position marked "A". At this location the stream flows in a southwesterly direction for a few feet before entering a fracture in the bedrock. In a matter of a few days the tracer dye was identified in the Fountain well water. Thus water in the stream enters the bedrock aquifer at point A and flows in a southwestward direction to the Fountain well.

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3. Hoffman, D. W., M. H. Miller and R. E. Wicklund, 1967, The Soils of Lanark County, Report No. 40 of the Ontario Soil Survey Research Branch, Canada Department of Agriculture and Ontario Department of Agriculture and Food.

It has also been shown that the two wells on the Rolph-Clark-Stone property are hydraulically mutually independent. Pumping at a rate of 250 gpm from either well does not cause any appreciable drawdown in the other well. Similarly, the pumping does not affect the water level in the nearby Hershey well nor have the Fountains noticed any affect of Rolph-Clark-Stone's pumping on their well water level. This suggests that at least three aquifers exist in the area with limited to non-existent hydraulic connection between them.

WATER QUALITY

A. General

Upon receiving Mr. Clarke's request for an investigation of well water quality problems at Smiths Falls, a well water sampling program was begun by representatives of the Water Quantity Management Branch. The collected samples were analyzed for fecal coliform, enterococcus, coliform, sulphate reducing and background bacteria, phenol, ethyl acetate, toluene, B.O.D., C.O.D., pH, hardness, alkalinity, specific conductance, colour dilution, total solids, MBAS as LAS, NH_4^+, NO_3^-, $NO_2^=$, Kjeldahl, nitrogen, total phosphorous, soluble phosphorous, chloride, sulphate, sulphide, calcium, magnesium, sodium, potassium and iron. The analytical results of this sampling program are shown in Table 1.

As previously stated, water quality in the individual wells was reported to be fresh at the time of drilling. The Flegg well may be used as a representative well for background quality. The water is free of taste, odour and colour problems. It is hard and does contain undesirable bacteria. This would be expected with water from a fractured calcareous sandstone aquifer with little overburden available for the renovation of septic wastes.

Mr. and Mrs. Fountain have experienced a deterioration of their well water quality with taste and odour problems first occurring in May, 1973. The resulting well water sampling program has shown that varying concentrations of iron sulphide and hydrogen sulphide are present in the Fountain well water. These substances have caused the complainant's taste, odour and colour problems.

Other wells in the area yield water that is hard and contains bacteria indicative of the entrance of septic waste water into the aquifer. Unacceptable concentrations of nitrate-nitrogen are also present in several wells, again as a result of the entrance of septic wastes into the aquifer. However, no other private wells in the area appear to contain waters having taste, odour and colour problems similar to that experienced in the Fountain well.

B. Well Water Contaminants

Several local wells contain septic waste contaminants which include bacteria and organic waste material. This problem, while remotely connected to the present study, will not be dealt with in detail because of the local Health Unit's responsibility in this area.

Obviously the complainant's problem deals with the presence of hydrogen sulphide, H_2S, and iron sulphide, FeS, in the water. These substances often occur naturally in bedrock aquifers in the Smiths Falls area. At the concentrations being dealt with, see Table 1, these contaminants do not present a concern physiologically. They are objectionable due to their odour, taste and colour characteristics and because of the corrosion of plumbing and fixtures by H_2S. Iron sulphide can also discolour clothes and fixtures.

Because of the concern that dumping of ink waste material and solvents by the industry may be causing the complainant's problems, samples of the water were analyzed for hydrocarbon content. Since no standard procedure was available for the determination of trace concentrations of ethyl acetate and toluene, approximately one month was required for method development and to complete the analyses of these samples[4].

The analyses results are presented in Table 1. Gas chromatography does not positively confirm the identity of ethyl acetate and toluene by itself, but the peaks in the gas chromatogram have identical retention times as these compounds[4]. Neither the toluene nor ethyl acetate found in the Fountain and Rolph-Clark-Stone wells are present in concentrations that are detectable by either taste or odour, nor are they present in concentrations that are physiologically objectionable[5].

To ascertain if any connection was apparent between the presence of the hydrocarbons and the sulphides in the affected wells, an extensive survey was undertaken which involved sampling 24 wells in the area. An analysis of the data in Table 1 will show that only two wells in the area contained the hydrocarbon contaminant, that only the complainant's well contained sulphides and that four wells in the study area contained sulphate reducing bacteria. The Fountain and Rolph-Clark-Stone wells alone contained both the contaminant and the bacteria.

"These bacteria are undesirable in an aquifer because they can potentially generate H_2S and cause corrosion of iron pipes if given the proper environmental conditions (i.e. presence of $SO_4^{=}$, organic matter, anaerobiosis). From a public health standpoint, Desulfovibrio, the characteristic sulphate-reducer is not hazardous per se."[6]

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4. Personal Communication, Dr. A. Nicholson, Division of Laboratories, Ministry of the Environment.
5. U. S. Environmental Protection Agency, 1971, Water Quality Criteria Data Book, Volume 1, Organic Chemical Pollution of Freshwater.
6. Personal Communication, Mr. F. R. Thompson, Division of Laboratories, Ministry of the Environment.

Upon the recommendation of Mr. G. Clarke, Industrial Wastes Branch, Ottawa, the industry ceased the dumping of their waste ink and solvents. A rapid decline in the contaminant concentration was observed in the Fountain well after November 1, 1973. With this decline to a total absence of the contaminant throughout December, 1973, it was observed that the water on January 5, 1974, no longer contained a black sulphide precipitate nor a strong odour of hydrogen sulphide. An interrelationship thus appeared to exist between the contaminant and the taste and odour problems experienced in the Fountain well water.

C. Contaminant Reactions within the Aquifer

"The great abundance of sulphate-reducers in the Fountain, Hershey and Rolph-Clark-Stone wells indicates a ground water pollution problem in that vicinity. Industrial wastes containing toluene, ethyl acetate and other organics discharged into an aquifer containing natural sulphate concentrations would present a favourable environment for growth of Desulfovibrio. Heterotrophic bacteria would decompose the complex waste organics in the soil and generate reduced compounds such as organic acids and H_2 which in the presence of sulphate would then serve as growth and energy sources for Desulfovibrio. These soluble materials may leach to the subsoil and/or aquifer where anaerobic sites would be conducive to growth and activity of the sulphate-reducers. Excessive multiplication of these bacteria would take place and many cells might easily reach the aquifer and be transferred through fissures in the rock."[6]

"The activity of high numbers of sulphate-reducers in the Fountain well is likely the cause of the black particles of FeS and the foul odour of H_2S."[4] Naturally occurring SO_4 is reduced in the aquifer to produce the highly reactive H_2S gas. The H_2S dissolved in water reacts with oxygen from dissolved air to produce a grey precipitate of sulphur. "H_2S cannot be generated in the presence of O_2, i.e. Eh of the system must be below -150mV for the anaerobic bacteria to be active. But when anaerobically generated H_2S moves into an oxygenated environment, then spontaneous sulphide oxidation and sulphur precipitation readily occurs."[6] After the dissolved oxygen has been removed, excess H_2S will react with iron and other ions, such as manganese that are present to form black precipitates of FeS, MnS, etc.

"It appears that the sulphate-reducers have penetrated deep into the aquifer since these were the only types of bacteria detected in the very deep Hershey well.

"There is no correlation between counts of sulphate-reducer, total plate count or coliforms in the samples. Sulphate-reducers are not necessarily associated with septic or fecal wastes. The fecal coliforms detected in the McMillian and Barber well waters likely originate from a septic human or animal waste and not the industrial waste in question. However, the sulphate-reducers appear to originate from pollutants of an industrial or chemical nature in the region of the Fountain, Hershey and Rolph-Clark-Stone wells."[6]

Because of the interdependence of the chemical and bacterial reactions that have resulted in the degradation of the Fountain's well water, it was anticipated that the removal of the energy source from the system would result in the return of the aquifer water to background quality.[7] From the data in Table 1, it is evident that ethyl acetate and toluene were not found in the Fountain well through the month of December. In the absence of this energy source, the activity of the bacteria was reduced resulting in the system becoming more aerobic because of reduced bacterial consumption of O_2 in degrading waste organics.[6] As a result, the H_2S concentration in the aquifer was seen to be dramatically reduced while nitrate and sulphate concentrations began to increase. On January 5, the writer observed only a very faint H_2S odour in the water and noted that no grey or black precipitate was present in the water. The water had a rusty orange colour characteristic of iron in an oxidized state. This was confirmed by a further rise in the sulphate concentration. However, the presence of H_2S along with Fe and NO_3 in the well water does indicate that more than one aquifer is being tapped by the Fountain well. These substances cannot mutually coexist because of their anaerobic and aerobic characteristics respectively.[7]

DISCUSSION AND CONCLUSIONS

Mr. and Mrs. Fountain of the Township of Montague have experienced a deterioration of their well water quality. Their complaints resulted in an extensive investigation by this Ministry. The analytical results of the well water sampling program indicate that water containing toluene and ethyl acetate has entered aquifers tapped by the Rolph-Clark-Stone and Fountain wells. The presence of this contaminant in the aquifer has resulted in a chain of bacterial reactions with two of the by-products being H_2S and FeS, the substances giving the Fountain well water its "rotton egg" odour, bad taste and dark colour. There is also evidence that septic wastes are entering the aquifer resulting in nitrate and bacterial contamination of many of the local wells.

The complainants are of the opinion that materials dumped by Rolph-Clark-Stone have affected the quality of their well water. Industry representatives indicated that ethyl acetate and toluene were solvents used within the plant and dumped at the rear of the plant. Analyses of the dumped material has shown that the hydrocarbon contaminants in the Fountain well are similar to those being dumped by Rolph-Clark-Stone.

The dump area is situated on well drained till material overlying fractured sandstone. Leachate from the dumped material could move easily through the thin overburden material to enter the underlying rock aquifer. Ethyl acetate in particular is very soluble in water. Once having entered the aquifer, the flow direction of the contaminant is difficult to determine. Generally, the

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7. Personal Communication, Mr. J. Dart, Research Branch, Ministry of the Environment.

flow of ground water in the area would be expected to be in a southeastward direction. However, a tracer study completed by local Health Unit representatives has shown that at least one component of local ground water flow is in a southwesterly direction. The most significant implication of this particular study is the demonstration of hydraulic connection between the stream in the vicinity of the Morrison property and the Fountain well. Therefore, any pollutants in the creek will reach the Fountain well. On this basis alone, the Fountain well water is not considered to be a satisfactory domestic supply. Finally, the complexity of aquifer hydraulics in the area has been shown by the lack of connection between the high capacity wells of Rolph-Clark-Stone and Hershey. At least three aquifers exist within the sandstone bedrock with limited to non-existent hydraulic connection between them. These local aquifer characteristics have made the definition of flow patterns in the bedrock impossible with our present knowledge. Only with further tracer studies might it be possible to determine whether material dumped by Rolph-Clark-Stone behind their plant has moved to the complainant's well.

While the flow path of the contaminant into the complainant's well is not clear, the reactions that have taken place within the aquifer have been defined. The hydrocarbon contaminants have been broken down by heterotrophic bacteria resulting in reduced compounds which have served as growth and energy sources for sulphate reducing bacteria. These bacteria have reduced the naturally occurring SO_4 in the aquifer with the end products being S, H_2S , MnS and FeS. The noxious end product production is dependent upon the presence of the hydrocarbon contaminant and an anaerobic environment. Stopping the entrance of the contaminant into the aquifer, oxidizing the by-product contaminants, killing the nuisance bacteria present and forcing oxygen into the aquifer to keep the system aerobic should satisfactorily improve the aquifer water, possibly to a state better than its original quality.

It is clear from a study of the data in Table 1 that the only domestic water supply affected in the area is that of Mr. Fountain. At no time has the Carr well or any other well in the area demonstrated the presence of hydrocarbon contaminated well water.

ALTERNATE SOURCES OF SUPPLY

Several alternatives could be attempted to restore potable supplies to affected residents. These include:

(a) The Fountain well could be treated, assuming the source of hydrocarbon contamination has been eliminated.[7] This treatment should include 1) putting approximately one quart of chlorinated laundry bleach (5% available chlorine) directly into the well, 2) surging the well to mix the solution and remove organic and sulphide precipitate build-ups in the well and aquifer, 3) resting the well for at least 12 hours to permit

the chlorine to oxidize the sulphides and kill the bacteria present, and 4) pumping the well to waste at capacity for at least four hours or until the chlorine taste is no longer present in the well. This treatment should be repeated a second time with a slight modification. Rather than allowing the chlorine solution to rest solely in the well, it should be circulated throughout the plumbing system and left within the system for at least 12 hours. Step 4) should then be repeated, remembering that at no time should the chlorine solution be discharged to the septic tank.

Without further hydrocarbon contamination of the aquifer, the well water quality of the affected wells should return to background quality.

(b) It may be possible to obtain an uncontaminated supply of water from a deeper bedrock aquifer. However, there is no certainty that such a supply exists. It would be imperative to case and grout off any contaminated zones to prevent the introduction of affected water into the deeper aquifer via the well bore. It may be necessary to drill and case to a depth of at least 80 feet. Considering the direct connection between surface water and the Fountain well water that has been demonstrated by the tracer study, a combination of this alternative and the previous alternative would be logical to ensure a long range potable water supply for the Fountain residence. If such action is undertaken further dye tracer studies should be completed to ensure the lack of communication between deeper aquifers and surface waters.

(c) It may be possible for the affected resident to obtain water from the Town of SmithsFalls. A municipal water main is located within 50 feet of the Fountains. This possibility should be discussed with the appropriate officials.

(d) Water could be hauled.

RECOMMENDATIONS

(1) No further dumping of waste material should take place on the Rolph-Clark-Stone property.

(2) All solvent contaminated soil and waste material should be removed from the dump area and deposited at an approved site.

(3) The local health unit should advise all residents in the study area of the advisability of drinking the local well water with consideration being given to the concentrations of bacteria and nitrate in the well waters.

(4) The township and town should agree to implement the recommendation submitted in 1963 by the OWRC that the "Officials of the Township of Montague should continue in their efforts to promote the establishment of municipal water and sewage treatment facilities in the communities of Atironto and Carsville subdivisions".

(5) The stream in the vicinity of the Morrison property should be monitored by Ministry of the Environment representatives to determine if this water is contaminated with hydrocarbons present in the Fountain well water.

(6) A tracer study should be completed by Ministry of the Environment representatives to determine if waste material dumped on the Rolph-Clark-Stone property could migrate to the complainant's wells.

(7) The wells in the Morrison property which are not serving as supply wells should be completely sealed in accordance with Ministry of the Environment regulations.

Report by: F R Campbell

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Approved by: T. J. Yakutchik

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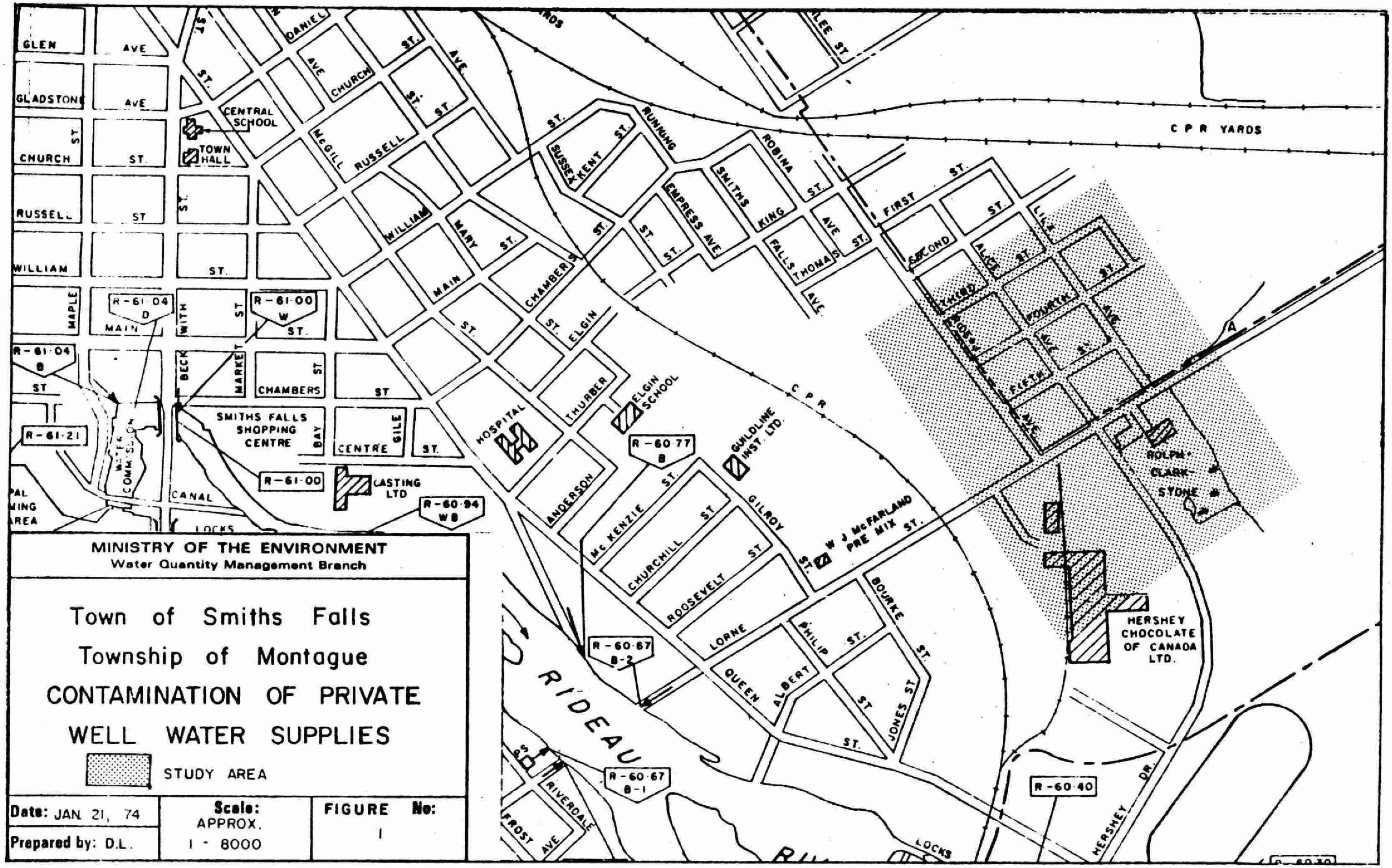
Supervisor,
Surveys and Projects Section,
Water Quantity Management Branch.

FRC:ce
February 8, 1974.

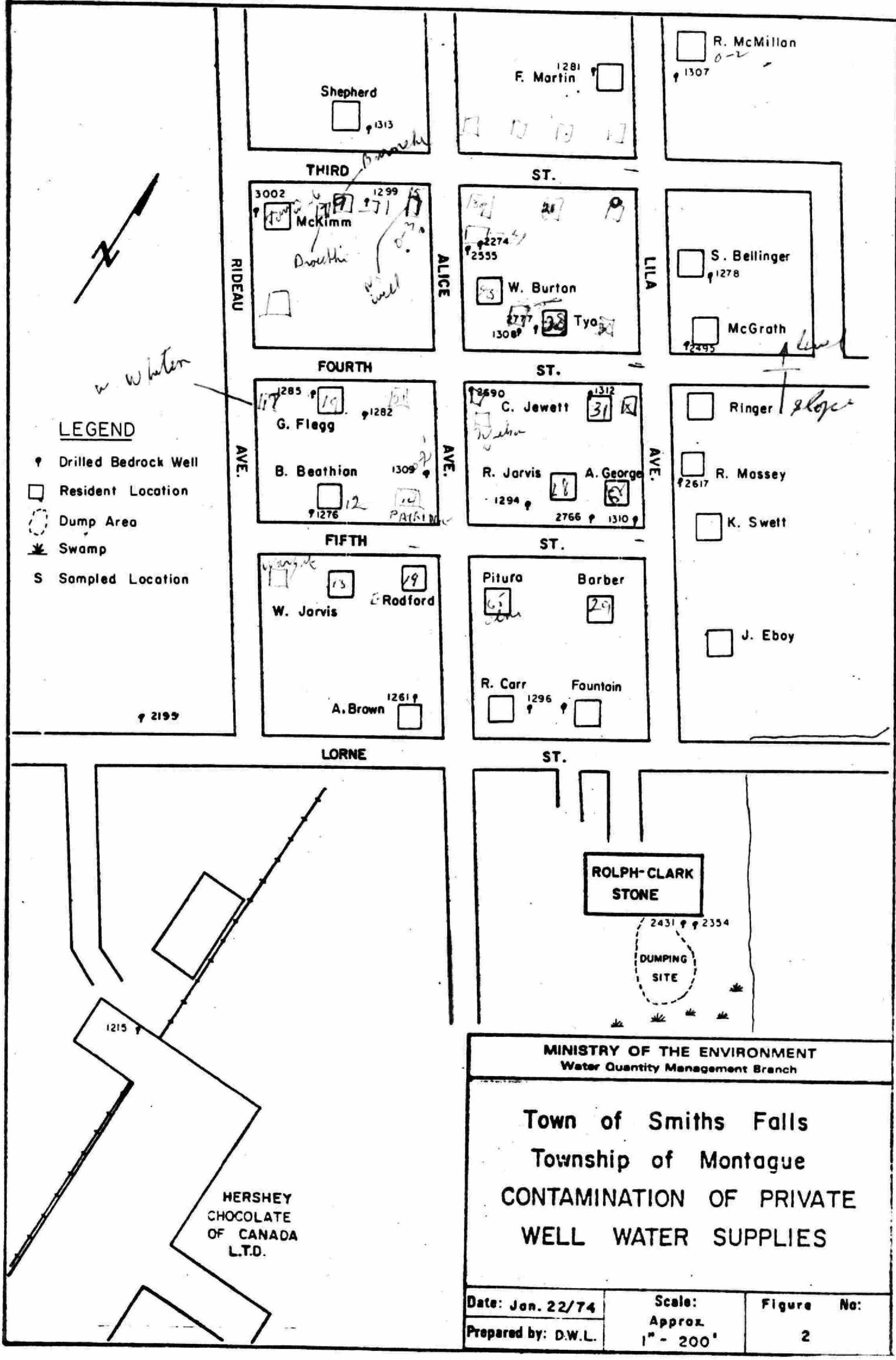


MINISTRY OF THE ENVIRONMENT
Water Quantity Management Branch

Town of Smiths Falls
Township of Montague
CONTAMINATION OF PRIVATE WELL WATER SUPPLIES

STUDY AREA

Date: JAN 21, 74	**Scale:** APPROX. 1 - 8000	**FIGURE No:** 1
Prepared by: D.L.		



R. McMillan
F. Martin
Shepherd
THIRD ST.
McKimm
W. Burton
Tyo
S. Bellinger
McGrath
RIDEAU AVE.
ALICE AVE.
LILA AVE.
FOURTH ST.
G. Flegg
B. Beathion
C. Jewett
R. Jarvis
A. George
Ringer
R. Massey
K. Swett
FIFTH ST.
W. Jarvis
Radford
A. Brown
Pitura
Barber
R. Carr
Fountain
J. Eboy
LORNE ST.
LEGEND
Drilled Bedrock Well
Resident Location
Dump Area
Swamp
S Sampled Location
ROLPH-CLARK STONE
DUMPING SITE
HERSHEY CHOCOLATE OF CANADA L.T.D.
MINISTRY OF THE ENVIRONMENT
Water Quantity Management Branch
Town of Smiths Falls
Township of Montague
CONTAMINATION OF PRIVATE WELL WATER SUPPLIES
Date: Jan. 22/74
Prepared by: D.W.L.
Scale: Approx. 1" - 200'
Figure No: 2

MINISTRY OF THE ENVIRONMENT

TABLE 1 Summary of Water Analyses FOUNTAIN

Prepared by D. LAVER

	BACTERIOLOGICAL																Chemical Constituents in parts per million (ppm)														
	FECAL COLIFORM	ENTEROCOCCI	BACKGROUND COLONIES	COLIFORM BACTERIA	SO_4 REDUCING BACT.	PHENOLS	ETHYL ACETATE (ppm)	TOLUENE (ppm)	B.O.D.	C.O.D.	pH of Lab.	HARDNESS as $CaCO_3$	ALKALINITY as $CaCO_3$	SPECIFIC CONDUCTANCE mmhos at 25°C	COLOUR DILUTION	TOTAL SOLIDS	MBAS as LAS	NITROGEN NH_4	NITROGEN NO_3	NITROGEN NO_2	NITROGEN Kjeld	PHOSPHOROUS (P) TOTAL	PHOSPHOROUS (P) SOL.	CHLORIDE (Cl)	SULPHATE as (SO_4)	SULPHIDE as (H_2S)	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	POTASIUM (K)	IRON (Fe)
OCT. 11						8																									
OCT. 16	0	0	134	78			PRESENT	PRESENT	6.0	<20	7.1		271		<1:40		<0.1		.22	.012	.52	.010		92	32	0	96	17	56	3.5	6.0
OCT. 24 11:50							PRESENT	PRESENT					386	1000		500		.01	<.01	.002	.42	.016		89	22	0	118	33	46	4.2	3.7
OCT. 24														998										88	23	0					3.0
OCT. 24 12:35 12:45														998 998										88 88	23 23	0 0					2.8 2.8
OCT. 24 1:00													399	1000		550		<.01	<.01	.002	.42	.010		88	23	0	123	30	46	4.2	2.5
NOV. 1	4	0	792	30			TRACE	3																		0.15 + <0.1					3.7 + 4.8
NOV. 19					11000		N.D.	PRESENT			7.1	356	326	780			<0.1	.05	.03	.010	.36	.014	.002	62	21	.05	104	23	38	2.8	4.0
DEC. 17	0	0	10	6			N.D.	N.D.				384	336						.18					41	37		112	25	25	2.9	
DEC. 27								N.D.	3.0	<20		358	314						1.2					53	30	0.5	103	24	27	3.6	
JAN. 5								N.D				274	219	560					.55					28	46	0	80	18	15	2.7	3.6
JAN. 15 + 16							N.D.	4	>14	50	7.3	384	356	745			<.01	<.01	<.01	.002	.45	.025	.004	43	11	2.5	110	26	24	2.7	7.2

MINISTRY OF THE ENVIRONMENT

TABLE I — Summary of Water Analyses — ROLPH-CLARK-STONE

Prepared by D. LAVER

	Bacteriological: Fecal Coliform	Bacteriological: Enterococcus	Bacteriological: Background Colonies	Bacteriological: Coliform Bacteria	SO_4 Reducing Bact.	Phenols	Ethyl Acetate (ppm)	Toluene (ppm)	B.O.D.	C.O.D.	pH of Lab.	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Specific Conductance mmhos at 25°C	Colour Dilution	Total Solids	MBAS as LAS	Nitrogen NH_4	Nitrogen NO_3	Nitrogen NO_2	Nitrogen Kjeld	Phosphorous (P) Total	Phosphorous (P) Sol.	Chloride (Cl)	Sulphate as (SO_4)	Sulphide as (H_2S)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Iron (Fe)
OCT. 11						0																									
OCT. 16	0	0	0	0			PRESENT	PRESENT	0.8	<20	7.2		241		<1:1		<0.1		.91	.016	.24	.004		48	51	0	82	25	22	3.8	.10
NOV. 1	0	0	6	2																											
NOV. 19					4600		PRESENT	PRESENT			7.3	320	246	670			<0.1	.02	1.7	.010	.18	.006	.005	43	51	<0.1	93	21	21	3.2	.30
DEC. 17	0	0	0	0			N.D.	.3				328	253						1.0					45	52		95	22	23	3.8	
DEC. 27								<0.5	2.5	<20		316	244						.78					43	51	<0.1	91	21	22	3.6	
JAN. 5								<0.5				320	248	680					1.4					48	51	0	93	21	24	3.7	.30
JAN. 15+16							N.D.	N.D.	0.4	<20	7.3	304	240	650			<0.1	<.01	1.3	.006	.18	.008	.002	30	52	<0.1	90	19	21	3.4	.17
HERSHEY PLANT																															
NOV. 19					46000						7.2	312	237	680			<0.1	.02	.90	.005	.13	.006	.002	47	52	<0.1	91	20	23	3.2	.15
DEC. 17	0	0	0	0			N.D.	N.D.				320	245						1.1					43	54		94	21	22	3.7	
DEC. 27								N.D.	0.6	<20		312	243						.89					40	51	<0.1	90	21	20	3.4	

Chemical Constituents in parts per million (ppm)

MINISTRY OF THE ENVIRONMENT

TABLE 1 Summary of Water Analyses C. JEWETT Prepared by D. LAVER

	BACTERIOLOGICAL: FECAL COLIFORM	ENTEROCOCCI	BACKGROUND COLONIES	COLIFORM BACTERIA	SO_4 REDUCING BACT.	PHENOLS	ETHYL ACETATE (ppm)	TOLUENE (ppm)	B.O.D.	C.O.D.	pH at Lab.	HARDNESS as $CaCO_3$	ALKALINITY as $CaCO_3$	SPECIFIC CONDUCTANCE mmhos at 25°C	COLOUR DILUTION	TOTAL SOLIDS	MBAS as LAS	Chemical Constituents in parts per million (ppm): NITROGEN NH_4	NO_3	NO_2	Kjeld	PHOSPHOROUS (P) TOTAL	SOL.	CHLORIDE (Cl)	SULPHATE as (SO_4)	SULPHIDE as (H_2S)	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	POTASSIUM (K)	IRON (Fe)
OCT. 19														720			<0.1		2.0	.003	.38	.004	.004		49	0	101				.05
NOV. 1	0	0	0	0																											
NOV. 19											7.1	360	259	740			<0.1	.01	3.1	.003	.31	.003	.003	52	52	<0.1	104	25	23	5.0	.01
R. MASSEY																															
OCT. 19														700			0.1		1.9	.008	.42	.064	.017		49	0	98				2.0
NOV. 1	0	0	856	28																											
NOV. 19											7.5	324	257	680			<0.1	.02	1.3	.019	.30	.002	.001	34	51	<0.1	95	21	18	3.7	.20
K. SWETT																															
OCT. 19														880			<0.1		6.2	.007	.30	.018	.017		48	0	115				<.05
NOV. 1	0	0	0	0																											
NOV. 19											7.2	424	288	980			<0.1	.01	7.0	.005	.26	.018	.005	102	51	<0.1	125	27	41	8.5	<.05

MINISTRY OF THE ENVIRONMENT

TABLE I Summary of Water Analyses E. RODFORD

Prepared by D. LAVER

	BACTERIOLOGICAL				SO_4 RE-DUCE-ING BACT.	PHEN-OLS	ETHYL ACET-ATE (ppm)	TOL-UENE (ppm)	B.O.D.	C.O.D.	pH of Lab.	HARD-NESS as $CaCO_3$	ALKA-LINITY as $CaCO_3$	SPECIF-IC CON-DUCT-ANCE mmhos at 25°C	COL-OUR DIL-UTION	TOTAL SOLIDS	MBAS as LAS	Chemical Constituents in parts per million (ppm)													
	FECAL COLI-FORM	ENTER-OCOCUS	BACK-GROUND COL-ONIES	COLI-FORM BACT-ERIA														NITROGEN				PHOSPHOROUS (P)		CHLOR-IDE (Cl)	SUL-PHATE as (SO_4)	SUL-PHIDE as (H_2S)	CAL-CIUM (Ca)	MAG-NESIUM (Mg)	SODIUM (Na)	POT-ASIUM (K)	IRON (Fe)
																		NH_4	NO_3	NO_2	Kjeld	TOTAL	SOL								
OCT. 19														700			<0.1		1.1	.008	.17	.004	.004		52	0	91				0.20
NOV. 1	0	0	0	0																											
NOV. 19											7.1	328	250	700			<0.1	.02	1.7	.021	.16	.002	.001	48	54	<0.1	95	22	24	3.7	.15
A. BROWN																															
OCT. 19														680			<0.1		.80	.011	.24	.004	.003		38	0	80				.10
NOV. 1	0	0	0	0																											
NOV. 19					28						7.2	304	251	680			<0.1	.01	.68	.020	.20	.005	.004	52	38	<0.1	90	19	29	23	<.05
B. BEATHIAN																															
OCT. 19														780			<0.1		3.3	.003	.27	.003	.003		46	0	107				<0.05
NOV. 1	0	0	0	2																											
NOV. 19											7.1	364	277	790			<0.1	.01	3.9	.006	.28	.002	.002	60	47	<0.1	105	24	29	5.7	<.05

MINISTRY OF THE ENVIRONMENT

TABLE / Summary of Water Analyses CARR

Prepared by D. LAVER

	BACTERIOLOGICAL: FECAL COLI-FORM	ENTEROCOCCUS	BACKGROUND COL-ONIES	COLI-FORM BACT-ERIA	SO_4 RE-DUCE-ING BACT.	PHEN-OLS	ETHYL ACET-ATE (ppm)	TOL-UENE (ppm)	B.O.D.	C.O.D.	pH at Lab.	HARD-NESS as $CaCO_3$	ALKA-LINITY as $CaCO_3$	SPECIFIC CON-DUCT-ANCE mmhos at 25°C	COL-OUR DIL-UTION	TOTAL SOLIDS	MBAS as LAS	NITROGEN: NH_4	NO_3	NO_2	Kjeld	PHOSPHOROUS (P): TOTAL	SOL.	CHLOR-IDE (Cl)	SUL-PHATE as (SO_4)	SUL-PHIDE as (H_2S)	CAL-CIUM (Ca)	MAG-NESIUM (Mg)	SODIUM (Na)	POT-ASIUM (K)	IRON (Fe)
NOV. 1	2	4	144	34																						<0.1 + <0.1					.10 + .05
DEC. 17	0	0	10	0								348	279						3.0					59	42		102	22	31	3.5	
DEC. 27								N.D.				322	263						1.9					52	41	<0.1	93	21	30	3.6	
JAN. 5												346	262	750					3.1					61	43	0	96	26	28	3.6	.10
JAN. 15 + 16							N.D.	N.D.	0.2	<20	7.3	336	263	725			<0.1	<.01	2.2	.005	.20	.012	.006	58	39	<.01	96	23	26	3.1	<.05
											J. EBOY																				
OCT. 19														940			<0.1		10.0	.007	.29	.029	.027		53	0	126				<.05
NOV 1.	0	0	0	2																											
NOV. 19					3.6						7.1	440	297	980			<0.1	.01	11.0	.006	.22	.015	.004	92	53	<0.1	126	30	39	4.9	<.05
DEC. 17	0	0	0	0			N.D.	N.D.				452	283						11.0					97	51		131	30	38	5.5	

Chemical Constituents in parts per million (ppm)

MINISTRY OF THE ENVIRONMENT

TABLE I Summary of Water Analyses R. JARVIS Prepared by D. LAVER

	BACTERIOLOGICAL																		Chemical Constituents in parts per million (ppm)													
	FECAL COLIFORM	ENTEROCOCCUS	BACKGROUND COLONIES	COLIFORM BACTERIA	SO_4 REDUCING BACT.	PHENOLS	ETHYL ACETATE (ppm)	TOLUENE (ppm)	B.O.D.	C.O.D.	pH at Lab.	HARDNESS as $CaCO_3$	ALKALINITY as $CaCO_3$	SPECIFIC CONDUCTANCE mmhos at 25°C	COLOUR OIL-UTION	TOTAL SOLIDS	MBAS as LAS	NITROGEN NH_4	NITROGEN NO_3	NITROGEN NO_2	NITROGEN Kjeld	PHOSPHOROUS (P) TOTAL	PHOSPHOROUS (P) SOL	CHLORIDE (Cl)	SULPHATE as (SO_4)	SULPHIDE as (H_2S)	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	POTASIUM (K)	IRON (Fe)
OCT. 19														640			<0.1		.41	.13	.24	.002	.002		47	0	91				0.20
NOV. 1	0	0	6	6																											
NOV. 19					15						7.2	340	267	680			<0.1	.03	1.6	.13	.29	.003	.003	39	57	<0.1	96	24	17	4.7	<.05
A. GEORGE																															
OCT. 19														610			<0.1		1.0	.003	.24	.004	.003		48	0	93				0.15
NOV. 1	0	0	24	28																											
NOV. 19											7.1	404	305	940			0.1	.03	12.0	.070	.46	.006	.001	67	59	<0.1	121	24	43	12	.15
PITURA																															
OCT. 19														880			<0.1		3.2	.011	.22	.002	.002		43	0	117				0.20
NOV. 1	0	0	0	4																											
NOV. 19					2400						7.1	408	329	900			<0.1	.01	5.7	.018	.29	.002	.001	65	45	<0.1	117	28	37	8.0	0.15

MINISTRY OF THE ENVIRONMENT

TABLE 1 Summary of Water Analyses W. JARVIS Prepared by D. LAVER

	BACTERIOLOGICAL																Chemical Constituents in parts per million (ppm)														
	FECAL COLIFORM	ENTEROCOCCI	BACKGROUND COLONIES	COLIFORM BACTERIA	SO_4 REDUCING BACT.	PHENOLS	ETHYL ACETATE (ppm)	TOLUENE (ppm)	B.O.D.	C.O.D.	pH at Lab.	HARDNESS as $CaCO_3$	ALKALINITY as $CaCO_3$	SPECIFIC CONDUCTANCE mmhos at 25°C	COLOUR DILUTION	TOTAL SOLIDS	MBAS as LAS	NITROGEN NH_4	NITROGEN NO_3	NITROGEN NO_2	NITROGEN Kjeld	PHOSPHOROUS (P) TOTAL	PHOSPHOROUS (P) SOL	CHLORIDE (Cl)	SULPHATE as (SO_4)	SULPHIDE as (H_2S)	CALCIUM (Ca)	MAGNESIUM (Mg)	SODIUM (Na)	POTASSIUM (K)	IRON (Fe)
OCT. 19														700			<0.1		2.1	.002	.22	.004	.004		44	0	94				<0.05
NOV. 1	0	0	92	6																											
NOV. 19					240						7.1	308	246	660			<0.1	.01	1.5	.003	.18	.004	.004	44	40	<0.1	93	18	25	3.1	<.05
DEC. 17	0	0	0	0			N.D	N.D.				328	264						1.3					45	44		96	21	28	4.1	
RINGER																															
OCT. 19														620			<0.1		.48	.003	.41	.004	.004		41	0	83				.05
NOV. 1	0	0	16	4																											
NOV. 19											7.3	324	254	640			<0.1	.01	1.5	.002	.30	.11	.002	30	52	<0.1	93	21	17	3.1	<.05
DEC. 17	0	0	0	0			N.D.	N.D.				316	239						45					30	53		93	20	17	3.6	

MINISTRY OF THE ENVIRONMENT

TABLE 1 Summary of Water Analyses McGRATH

Prepared by D. LAVER

	Bacteriological: Fecal Coliform	Enterococcus	Background Colonies	Coliform Bacteria	SO_4 Reducing Bact.	Phenols	Ethyl Acetate (ppm)	Toluene (ppm)	B.O.D.	C.O.D.	pH at Lab.	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Specific Conductance mmhos at 25°C	Colour Dilution	Total Solids	MBAS as LAS	Chemical Constituents in parts per million (ppm): Nitrogen NH_4	Nitrogen NO_3	Nitrogen NO_2	Nitrogen Kjeld	Phosphorous (P) Total	Phosphorous (P) Sol	Chloride (Cl)	Sulphate as (SO_4)	Sulphide as (H_2S)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Iron (Fe)
NOV. 19											7.3	332	252	700			<0.1	.01	1.0	.003	.30	.003	.002	61	49	<0.1	96	21	21	3.7	<.05
S. BELLINGER																															
NOV. 19											7.1	388	266	860			<0.1	.01	3.2	.009	.24	.014	.006	82	58	<0.1	118	21	28	7.8	.35
R. McMILLIAN																															
NOV. 19											7.1	388	300	920			0.1	.29	2.3	.016	.84	.048	.028	66	88	<0.1	118	22	52	8.3	<.05
DEC. 17	0	0	4	6			N.D.	N.D.				304	229											25	81		93	18	23	5.3	
F. MARTIN																															
NOV. 19											7.2	340	265	720			<0.1	.01	2.1	.002	.40	.078	.009	37	65	<0.1	99	22	25	5.4	4.4
McKIMM																															
NOV. 19											7.2	130	86	270			<0.1	.02	.10	.002	.31	.012	.002	12	41	<0.1	38	8	4	1.7	.05
W. BURTON																															
NOV. 19											7.1	372	284	830			<0.1	.01	5.0	.003	.44	.071	.068	64	57		115	20	30	11	<.05

MINISTRY OF THE ENVIRONMENT

TABLE 1 Summary of Water Analyses BARBER

Prepared by D. LAVER

	BACTERIOLOGICAL																	Chemical Constituents in parts per million (ppm)														
	FECAL COLI-FORM	ENTEROCOCCUS	BACKGROUND COL-ONIES	COLI-FORM BACT-ERIA	SO_4 RE-DUCE-ING BACT.	PHEN-OLS	ETHYL ACET-ATE (ppm)	TOL-UENE (ppm)	B.O.D.	C.O.D.	pH at Lab.	HARD-NESS as $CaCO_3$	ALKA-LINITY as $CaCO_3$	SPECIF-IC CON-DUCT-ANCE mmhos at 25°C	COL-OUR DIL-UTION	TOTAL SOLIDS	MBAS as LAS	NITROGEN NH_4	NO_3	NO_2	Kjeld	PHOSPHOROUS (P) TOTAL	SOL	CHLOR-IDE (Cl)	SUL-PHATE as (SO_4)	SUL-PHIDE as (H_2S)	CAL-CIUM (Ca)	MAG-NESIUM (Mg)	SODIUM (Na)	POT-ASIUM (K)	IRON (Fe)
OCT. 19														980			<0.1		8.5	.005	.35	.025	.024		51	0	126				0.10
NOV. 1	14	0	1480	248																											
NOV. 19					93						7.1	396	296	960			0.1	.04	8.5	.013	.50	.021	.007	82	54		120	23	47	13	<.05
DEC. 17	0	0	0	6			N.D.	N.D.				372	276						9.6					79	52		114	21	45	13	
G. FLEGG																															
OCT. 19														820			<0.1		5.4	.003	.25	.008	.008		52	0	104				<.05
NOV. 19							N.D.	N.D.			7.1	368	278	840			<0.1	.01	8.0	.002	.37	.008	.007	57	52	<0.1	112	21	35	11	<.05
SHEPHERD																															
NOV. 19					3.6						7.2	360	270	850			<0.1	.01	4.0	.002	.26	.002	.002	71	60	<0.1	110	20	40	10	<0.5
TYO																															
NOV. 19											7.2	376	269	800			<0.1	.01	3.9	.002	.31	.007	.006	64	54	<0.1	107	26	28	7.3	.01

MINISTRY OF THE ENVIRONMENT

TABLE 1 Summary of Water Analyses LATHAN Prepared by D. LAVER

	BACTERIOLOGICAL																	Chemical Constituents in parts per million (ppm)													
	FECAL COLI-FORM	ENTEROCOCCUS	BACK-GROUND COL-ONIES	COLI-FORM BACT-ERIA	SO_4 RE-DUCE-ING BACT.	PHEN OLS	ETHYL ACET-ATE (ppm)	TOL-UENE (ppm)	B.O.D.	C.O.D.	pH at Lab.	HARD-NESS as $CaCO_3$	ALKA-LINITY as $CaCO_3$	SPECIF-IC CON-DUCT-ANCE mmhos at 25°C	COL-OUR OIL-UTION	TOTAL SOLIDS	MBAS as LAS	NITROGEN NH_4	NITROGEN NO_3	NITROGEN NO_2	NITROGEN Kjeld	PHOSPHOROUS (P) TOTAL	PHOSPHOROUS (P) SOL	CHLOR-IDE (Cl)	SUL-PHATE as (SO_4)	SUL-PHIDE as (H_2S)	CAL-CIUM (Ca)	MAG-NESIUM (Mg)	SODIUM (Na)	POT-ASSIUM (K)	IRON (Fe)
DEC. 27								N.D.	0.2	<20		298	243						.59					27	45	<0.1	88	19	14	2.9	
C. V. MORRISON																															
DEC. 27								N.D.	0.6	<20		306	238						1.9					35	49	<0.1	87	21	18	3.0	